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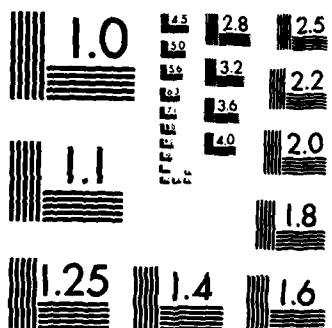
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Interim Report E-182
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**DETERMINATION OF CIVIL WORKS
ENERGY CONSUMPTION BASELINE**

by
B. J. Sliwinski

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petroleum fuels; one estimate shows that 90 percent of the total consumption is petroleum-related. The analysis results were used to derive energy consumption baselines for the major Civil Works activities: dredging, lock and dam operations, and mat laying. These baselines were determined to be as follows: dredging -- 58,000 Btu/cu yd; lock and dam operations -- 5×10^6 Btu/day; and mat laying -- 775,000 Btu/square of mat.

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FOREWORD

This study was conducted for the Directorate of Civil Works under Reimbursable Order CWO-M-81-18, entitled "Development of Energy Goals," dated May 1981. The work was performed by the Energy Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (CERL).

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DETERMINATION OF CIVIL WORKS ENERGY CONSUMPTION BASELINES

1 INTRODUCTION

Background

The Civil Works Program of the U.S. Army Corps of Engineers is responsible for water resource management at the national level. Civil Works responsibilities include navigation, flood control, hydroelectric power, water supply, recreational activities, and fish and wildlife conservation. The Civil Works Program consumes a great deal of energy, especially petroleum-related fuels, to do its work. The cost of this energy has increased greatly in the past several years; therefore, the Directorate of Civil Works (DCW), like other Army agencies, has been motivated to conserve energy as much as possible.

To insure that these energy conservation efforts are effective and properly directed, DCW must first develop a set of comparable and meaningful conservation goals for each of its activities. The first step in developing these goals, as done in this phase of the research, is to determine the relative amounts of energy consumed by the various activities and to determine baselines for energy consumption per unit of mission activity. The next phase of this research will be to identify viable energy conservation options and use this baseline data as the foundation for developing activity-specific fuel reduction goals.

Objective

The objective of this work was to determine energy consumption baselines for major Civil Works activities.

Approach

Data from the Defense Energy Information System was surveyed to determine:

1. The types and amounts of fuel that Civil Works activities consume
2. The categories under which consumption occurs.

Using this data and information from Corps Districts, Civil Works activities were closely examined to determine energy consumption baselines by activity.

2 EXAMINATION OF DEIS DATA

Civil Works energy consumption data is reported through the Defense Energy Information System (DEIS). CERL acquired DEIS data from the Facilities Engineering Support Agency (FESA) at Fort Belvoir, VA. Since the data was resident on the National CSS computer system, CERL accessed it directly.

DEIS data is divided into two categories: DEIS I and DEIS II. DEIS I provides data on consumption of petroleum products; DEIS II provides data on various types of energy consumed for utilities, such as natural gas, propane, electricity, fuel oil, coal, steam, hot water, and hydroelectric power.

Tables 1 and 2 show the format of the DEIS data as provided to CERL. The DEIS I data was summed for all Civil Works Districts to determine how petroleum fuels are being consumed (Table 3). In Tables 1 and 3, "primary" refers to mobility energy consumption; "secondary" refers to heating, ventilating, and air conditioning fuel consumption; "tertiary" refers to process energy consumption; and "dredge" refers to dredge fuel consumption. Of these categories, dredging and process activities consume the most fuel.

The large amount of energy consumed by dredging is understandable, since all the dredges are petroleum-fueled. The source of the large process energy consumption (tertiary) is probably mat laying, lock and dam activities, and in some cases, pumping stations.

The DEIS II data was summed similarly (Table 4). If only buildings are considered, electricity is the largest form of energy consumed. Overall, however, petroleum products represent the largest form of energy use.

Table 1

DEIS Summary Report for Consumption of Petroleum
Products by Fiscal Quarter (Data in Millions of Btus)

District or Lab: Omaha

<u>FY</u>	<u>Quarter</u>	<u>Total Primary</u>	<u>Total Secondary</u>	<u>Total Tertiary</u>	<u>Total Dredge</u>	<u>Total Credit Card*</u>
80	03	5,958	338	2,384	0	4,216
	04	4,914	6	3,496	0	4,492
81	01	3,729	1,363	2,280	0	5,739
	02	<u>2,576</u>	<u>2,114</u>	<u>1,881</u>	<u>0</u>	<u>4,825</u>
		17,177	3,821	10,040	0	19,272

*Quantity of fuel purchased for mobility; that is, credit cards purchases for owned airplanes, autos, trucks and boats.

Table 2

DEIS II Summary Report for Utilities Energy
Consumption by Fiscal Quarter
(Data in Millions of Btus)

District or Lab: Omaha

<u>FY</u>	<u>Quarter</u>	<u>Product Code *</u>	Sum Owned Building (MBtus)	Sum Leased Building (MBtus)	Sum Owned Building (MBtus)	Sum Leased Process (MBtus)
80	03	DRD	0	0	0	0
		ELC	4,048	0	0	0
		FSX	337	0	2,383	0
		MOB	0	0	10,173	0
		NAG	12,046	0	0	0
		PPG	531	0	0	0
			<u>16,963</u>	<u>0</u>	<u>12,556</u>	<u>0</u>
	04	DRD	0	0	0	0
		ELC	5,800	0	0	0
		FSX	5	0	3,494	0
		MOB	0	0	9,405	0
		NAG	5,970	0	0	0
		PPG	864	0	0	0
			<u>13,639</u>	<u>0</u>	<u>12,899</u>	<u>0</u>
81	01	DRD	0	0	0	0
		EGO	2,450,006	0	0	0
		ELC	2,181	0	1,855	0
		FSX	1,361	0	2,278	0
		HYD	24,998	0	86,117	0
		MOB	0	0	8,557	907
		NAG	13,539	0	0	0
		PPG	314	0	157	0
		SHW	205	0	0	0
			<u>2,492,604</u>	<u>0</u>	<u>98,964</u>	<u>907</u>
	02	DRD	0	0	0	0
		EGO	2,139,593	0	0	0
		ELC	2,424	0	2,307	0
		FSX	2,112	0	1,877	0
		HYD	33,826	0	105,907	0
		MOB	0	0	4,007	593
		NAG	16,233	0	0	0
		PPG	530	0	97	0
		SHW	890	0	0	0
			<u>2,195,609</u>	<u>0</u>	<u>114,195</u>	<u>593</u>
			<u>4,718,814</u>	<u>0</u>	<u>238,615</u>	<u>1,500</u>

*The product codes are as follows: DRD - dredge fuel consumption; EGO - Electricity generated and used by others; ELC - Electrical energy consumption; FSX - Petroleum products consumed within buildings; NAG - Natural gas energy consumption; PPG - Propane gas energy consumption; HYD - Hydroelectric power consumption; MOB - Mobility fuel consumption; SHW - Steam and hot water energy consumption.

Table 3

DEIS I Data for Petroleum Fuels
Consumption (Millions of Btus)

DEIS I Totals (All Districts)						
<u>FY</u>	<u>Quarter</u>	<u>Primary</u>	<u>Secondary</u>	<u>Tertiary</u>	<u>Dredge</u>	<u>Total</u>
80	03	178,056	105,763	836,048	0	1,119,867
	04	160,834	20,981	1,431,591	0	1,613,406
81	01	125,269	46,753	827,431	1,315,827	2,315,280
	02	118,210	100,194	182,449	1,695,552	2,096,405
Grand Total		582,369	273,691	3,277,519	3,011,379	7,144,958

Table 4

DEIS II Data for Utilities Energy
Consumption (Millions of Btus)

<u>FY</u>	<u>Quarter</u>	<u>Product Code*</u>	<u>Buildings</u>	<u>Process</u>	<u>Total</u>
80	3	ELC	590,787		590,787
		FSX	105,735	836,025	941,760
		NAG	36,566		35,566
		PPG	4957		4957
80	4	ELC	695,895	6692	702,587
		FSX	20,513	1,431,120	1,451,633
		NAG	19,278		19,278
		PPG	5290		5290
81	1	ELC	557,905	72,455	630,360
		FSX	46,030	1,479,637	1,525,667
		NAG	61,745	1469	63,214
		PPG	5290		5290
81	2	ELC	495,980	259,748	755,725
		FSX	95,456	781,422	876,878
		NAG	90,300	3286	93,586
		PPG	14,035	3128	17,168

*ELC - electrical energy consumption; FSX - petroleum products consumed within buildings; NAG - natural gas energy consumption; PPG - propane gas energy consumption.

3 ANALYSIS OF ENERGY-CONSUMING ACTIVITIES

Dredging

Dredging consumes more fuel than any other single Civil Works activity. Most dredging is related to navigational projects, but a small percentage of the work is done for beach nourishment, flood control, and dike disposal. The number of Btus consumed per cubic yard of material dredged was estimated based on contacts with dredge operating Districts, the results of the national dredging survey (NDS),¹ and DEIS data.

Civil Works uses mostly hydraulic dredges, which can be divided into four categories: hopper, cutterhead, dustpan, or sidecaster. Each type is best suited for a specific set of operating conditions. For this analysis, average hourly or daily dredging capacity was based on historic data from the NDS. Data on the type and horsepower of each dredge's pump and propulsion system also came from the NDS. The average energy consumption per cubic yard for each dredge was estimated by assuming a set of efficiencies for components such as pumps, turbines, and diesel engines. These averages were calculated by dividing the total estimated energy consumption for all dredges of one type by the total cubic yards dredged by that type. The average energy consumption per cubic yard for all dredges was calculated by dividing the total energy consumption of all dredge types by the total cubic yards dredged.

Table 6 shows the accuracy of the estimation technique used. Actual dredge fuel consumption, as reported by the dredge operating District, is compared with the fuel consumption estimates that were based on dredge horsepower. Table 6 shows that the actual and estimated consumption for a dredge can vary by a factor of two (either high or low). However, comparing actual consumption (Table 6) with estimated consumption based on average energy use by type of dredge (Table 5) shows better agreement.

Table 5

Average Energy Consumption of Various Dredges

<u>Dredge Type</u>	<u>Estimated Btu/Cu Yd</u>	<u>Estimated Gal/Cu Yd (@ 140,000 Btu/Gal)</u>
Hopper	54,340	.388
Cutterhead	26,350	.188
Dustpan	10,080	.072
Sidescaster	39,650	.283
All Dredges	28,330	.202

¹ Dredging Market in the United States (Syncon Publishing Company, 1976).

Table 6

Estimated Versus Actual
Energy Consumption for Various
Dredges

<u>Dredge</u>	<u>Dredge Type</u>	<u>Estimated Btu/Cu Yd</u>	<u>Actual Btu/Cu Yd</u>
Comber	Hopper	84,130	45,090
Burgess	Dustpan	8,400	15,660
Ackerson	Dustpan	6,900	12,600
Fry	Sidecaster	31,540	26,180

A second estimate of energy consumed per cubic yard dredged was done using DEIS I data. This data was compared with actual after-dredge survey estimates from the St. Louis District for the Mississippi, Illinois, and Kaskaskia Rivers. The after-dredge survey data is a total of all material dredged in the District. The total for the first and second quarters of FY81 was 4,907,100 cu yd. The energy consumption for dredging from the DEIS I report was 293,426 million Btus. Thus, the estimated energy consumed was 59,800 Btu/cu yd.

A third estimate was done using the average total dredge yardage for FY77, FY78, FY79, and the FY81 DEIS I energy consumption data. Since yardage data was not available for FY81, and DEIS data before FY79 was not considered reliable, it was assumed that the FY81 yardage did not differ significantly from the average yardage for FY77, FY78, and FY79. This average yardage and the FY81 energy consumption provided an estimate of 58,100 Btu/cu yd. This figure represents an overall estimate for all of Civil Works.

The values for both the second and third estimates are a little more than twice the amount obtained from the NDS estimates of dredge horsepower (Table 5) and from actual reported dredge fuel consumption (Table 6); this is because the last two estimates include fuel consumption by dredges and support boats. These estimates can be considered an upper limit for fuel consumption of dredging operations.

Locks and Dams

Several Districts were contacted to obtain information on energy consumed in lock and dam operations. The St. Louis District provided detailed information on its five lock and dam operations. The information was in the form of motor horsepower and estimates of operating time for the various lock and dam equipment. Because estimates were in the form of operating time, it was not possible to determine energy per lockage. Instead, daily energy consumption was estimated for each site (Table 7). Data for Btu/day includes the sum of electrical consumption multiplied by the standard conversion factor of 3413 Btu/kWh and all other fuel consumed. The kWh/day figure is for electrical consumption only. It is interesting to note that diesel fuel and natural gas

comprise significant percentages of the energy used in St. Louis District lock and dam activities. The estimates for these lock and dam operations compare reasonably well with energy consumption figures reported by other Districts.

The Rock Island District estimated the annual electrical consumption of a typical lock to be 156,000 kWh. Using average kWh/day in Table 7, and assuming a 9-month operating season, an estimate of 214,650 kWh is obtained.

The New Orleans District reported a monthly consumption for Fort Allen lock of 18,500 kWh. This compares with an estimated 23,850 kWh/month in Table 7.

Perhaps the most surprising aspect of these estimates for lock and dam operations is how low they are. Given the Fort Allen lock data, and assuming 3.6 cents/kWh and a demand charge equal to 100 percent of the energy charge, the monthly electric bill would be only \$1332. This would be similar to the cost of fuel used for about 2 hours of dredging.

Pumping Stations

The Civil Works program operates pumping stations as part of flood control and water supply activities. Because of their large size, these stations are significant energy consumers. In urban areas, they are generally powered by electricity and in rural areas by diesel fuel.

Memphis District has 28 pumping stations. Of these, the District operates three: the Graham-Burke pumping station, W. G. Huxstable pumping station, and pumping station DD 17. Table 8 gives operating data for Huxstable and Graham-Burke. Operating data was not available for pumping station DD 17 because it was only recently installed.

A pumping station's power consumption is related to several variables: static head, dynamic head, pump efficiency, and engine efficiency. The data in Table 8 indicate that the daily fuel consumption for each station is remarkably constant; this shows that the daily operating conditions are also usually constant.

Table 7

Estimated Energy Consumption -- St. Louis District Locks and Dams

<u>Lock and Dam</u>	<u>Btu/Day</u>	<u>kWh/Day</u>	<u>% Electrical</u>	<u>% Diesel</u>	<u>% Other</u>
#24	2.40 x 10 ⁶	465.5	66	34	0
#25	3.50 x 10 ⁶	814.8	79	21	0
#26	11.5 x 10 ⁶	1008.1	31	6	63
#27	5.45 x 10 ⁶	1058.9	66	34	0
Kaskaskia	2.16 x 10 ⁶	632.2	100	0	0
Average	5.00 x 10 ⁶	795.9			

Table 8
Pumping Station Energy Consumption
(Petroleum-Fueled)

<u>Pumping Station</u>	<u>Year</u>	<u>Days of Operation</u>	<u>Fuel Consumed (Gal)</u>	<u>Daily Fuel Consumption (Gal/Day)</u>
Huxstable	1977	1.6	53,161	33,225
	78	18.6	360,749	19,395
	79	71.7	1,406,372	19,614
	80	30.6	677,384	22,136
	81	3.2	69,804	21,813
Graham-Burke	1975	115.4	271,026	2,348
	76	.7	1,596	2,280
	77	5.0	11,718	2,343
	78	117.0	274,722	2,348
	79	136.0	319,284	2,347
	80	23.0	70,350	3,058

The load fraction at which each station is presently operating was estimated, using number of engines, their horsepower, and the daily fuel consumption for each station. This value was 45 percent for Graham-Burke and 60 percent for Huxstable. A more detailed study done by the Memphis District indicated a 50 percent value for Huxstable. These figures provide an approximate method for determining the fuel consumption of a petroleum-fueled pumping station. If the typical pumping station is assumed to operate at 50 percent load:

$$\text{Hourly Fuel Consumption} = \text{Total Hp} \times 5092 \frac{\text{Btu}}{\text{Hr-Hp}} \times \frac{\text{Gal-Fuel}}{\text{Btu}} \times .50 \quad [\text{Eq 1}]$$

Pumping station operation may significantly affect whether consumption goals are met; therefore, when these goals are set, decision-makers must consider that pumping station operations are seasonal and that many Corps-operated pumping stations may be diesel-fueled.

Revetment Operations (Mat Laying)

Revetment operations stabilize river banks by the placing of articulated concrete mats. These operations use machines which consume large amounts of petroleum fuels.

The data in Table 9 were taken directly from the Memphis District Installation Energy Plan and show the amount of energy used to lay each square of concrete mat. The average energy consumption per square placed is 775,349 Btus or about 6 gal of fuel per square.

Table 9

Energy Per Square of Concrete Mat

	<u>FY77</u>	<u>FY78</u>	<u>FY79</u>	<u>FY80</u>
Energy (MBtu)	216,247	181,963	214,981	166,043
Number of Squares	278,569	330,223	164,396	231,822
Btu/Square	776,278	551,030	1,307,702	716,252

4 BASELINE IDENTIFICATION

The information available from various Civil Works Districts was adequate to determine baselines for the major energy consumers within Civil Works: dredging, locks and dams, and mat laying. These baselines are summarized in Table 10. These baselines should be used as a basis of comparison and as a tool for making ball-park estimates of energy consumption for the various activities.

Table 10

Summary of Civil Works Energy Consumption
Baselines for Major Activities

<u>Activity</u>	<u>Baseline</u>
Dredging	58,000 Btu/cu yd
Lock and Dam	5 X 10 ⁶ Btu/day
Mat Laying	775,000 Btu/square

Data for many of the smaller Civil Works activities, particularly those associated with recreation resources, were scattered and generally not suitable for determining baselines. While energy consumed by recreation facilities may sometimes be significant at the District level, it is not significant at the overall Civil Works level. This is because most energy consumption associated with recreation is electricity for lighting and campsites and fuel for vehicles (mobility). The total electricity used for all Civil Works activities accounts for only 10 percent of the total consumption, and recreation represents a small portion of this total. As shown in Table 3, mobility fuel consumption accounts for only 8 percent of total petroleum consumption.

The overall picture of Civil Works energy consumption shows a dependence on petroleum fuels. Based on the DEIS data examined, 67 percent of Civil Works energy consumption is petroleum-related and 33 percent is electricity-related. If these data are recalculated, using the standard conversion factor of 3413 Btu/kWh, rather than the 11,600 Btu/kWh used by DEIS, the breakdown of petroleum and electrical energy consumption is 90 percent and 10 percent, respectively.

The major energy users for which baselines were determined will be the starting point for developing energy conservation goals for these activities. Before proposing activity-specific goals, however, energy options which will be available within the next 18 years must be examined. This definition of the various options is necessary to develop realistic and defensible goals. The most likely options now appear to be:

1. Making a strong effort to use alternate fuels such as coal and alcohol.
2. Examining methods to improve the efficiency of dredging, mat laying, and pumping operations (the biggest petroleum users).

The goal development work during FY82-83 will consider aspects of items 1 and 2 above.

5 CONCLUSIONS AND RECOMMENDATIONS

This study showed that Civil Works activities are very dependent on petroleum fuels. One estimate, based on DEIS data, showed that about 90 percent of the energy consumed is petroleum-related.

Energy consumption baselines were determined for three major Civil Works activities: dredging, lock and dam operations, and mat laying. These baselines were determined to be: dredging -- 58,000 Btu/cu yd; lock and dam operations -- 5×10^6 Btu/day; and mat laying -- 775,000 Btu/square of mat.

It is recommended that the Corps consider investigating the use of alternate fuels as part of the overall goal of reducing petroleum fuel consumption by 75 percent over the next 18 years.

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